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The Limits of Authority: Motivation versus Coordination

Eric Van den Steen*

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Abstract

This paper studies the effects of open disagreement on motivation and coordination. It shows how – in the presence of differing priors – motivation and coordination impose conflicting demands on the allocation of authority, leading to a trade-off between the two.

The paper first derives a new mechanism for delegation: since the agent thinks – by revealed preference applied to differing priors – that his own decisions are better than those of the principal, delegation will motivate him to exert more effort when effort and correct decisions are complements. A need for implementation effort will thus lead to more decentralization. The opposite holds for substitutes.

Delegation, however, reduces coordination when people disagree on the right course of action. The paper shows that – with differing priors – the firm needs to rely more on authority (as opposed to incentives) to solve coordination problems, relative to the case with private benefits. An interesting side-result here is that the principal will actively enforce her decisions only at intermediate levels of the need for coordination.

The combination of the two main results implies a trade-off between motivation and coordination, both on a firm level and across firms. I derive the motivation-coordination possibility frontier and show the equilibrium distribution of effort versus coordination. I finally argue that strong culture, in the sense of homogeneity, is one (costly) way to relax the trade-off.

JEL Codes: D8, L2, M5

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1 Introduction

Motivation and coordination are two of the most central concerns in organization design. In particular, once people join hands in an organization, their actions must be coordinated

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to realize the benefits of organization, while they must also get motivated since they do not bear the full consequences of their actions any more (Milgrom and Roberts 1992). To a large extent, the problem of organization is to capture the benefits of specialization and scale while minimizing the motivation and coordination losses. In practice, this often leads to a trade-off between motivation and coordination. In fact, many of the key choices in organization design can be framed in terms of that trade-off.

This paper studies the interaction between, on the one hand, differing priors about the right course of action, and, on the other hand, motivation and coordination. In particular, the paper shows that – in the presence of differing priors – motivation and coordination impose conflicting demands on the allocation of authority, which causes a trade-off between the two.

To study these issues, I consider the setting of a manager-entrepreneur who undertakes a project and who needs to employ an agent to realize that project. In the context of this project, both the principal and the agent will need to make a decision, and the agent also needs to exert effort to execute his decision. The project’s success depends on the quality of the decisions; on the coordination between the decisions; and on the effort exerted by the employee. The principal can contract with the agent on the outcome of the project, and chooses to either control the agent’s decision or to delegate that decision to the agent.

The paper first derives a new rationale for delegation (when people may openly disagree on the right course of action). The starting point is the observation that – by revealed preference applied to differing priors – the agent believes that his own choices and decisions are better than these imposed by his principal. As a consequence, if effort is a complement¹ to making good decisions, then the agent will expect a higher return from his effort – and thus exert more effort – when he can make the decision himself. In other words, delegation will increase the agent’s effort or motivation. An important example of such effort that is a complement to correct decisions, is ‘implementation effort’ (i.e., effort to implement and execute a decision). The opposite result also holds: when effort is a substitute to correct decisions then delegation will decrease the agent’s effort. Since complementary effort seems to be the more likely of the two – as I discuss later – the key prediction here is that a need for implementation effort will favor delegation. I also argue that this result does not hold in a common prior/private information setting.

Delegation, however, reduces coordination when people disagree on the right course of action since each player will want to follow the course of action that he considers best. The key result here is that with differing priors we typically need to rely more on authority (relative to incentives) to solve coordination problems. In particular, while coordination problems that originate in private benefits may be mitigated or even eliminated through an appropriate allocation of residual income, this approach is less (if at all) effective when the coordination problem comes from differing priors. The reason is that – in the case of differing priors – shifting residual income to a player not only makes him internalize more of his externalities, but also increases his incentives to just do what he thinks is right. These

¹Effort is a complement to a decision if effort is more useful when the decision is correct than when the decision is wrong (and vice versa for being a substitute). I discuss these concepts and their implications in section 3 and appendix B.

two forces often go in opposite directions. In particular, in the model of this paper, the two effects exactly cancel each other out so that incentives are completely ineffective to get coordination. For an analogous model with private benefits, on the other hand, I do show that incentives can solve the coordination problem. More broadly, this result suggests that incentives are less effective to solve externalities when these externalities originate in differing priors.

An interesting – though less important – result is that the principal will actively enforce her decisions only when the importance of coordination is intermediate. The reason is that coordination being more important also gives the players reasons to try to coordinate on their own initiative, and thus makes active enforcement of centralized coordination decisions less necessary.

Combining these results leads to the final conclusion that disagreement induces a trade-off between coordination and motivation. I first show that – for exogenously given levels of incentives – firms face a trade-off between motivation and coordination, and derive the effort-coordination possibility frontier (Roberts 2004).² I further show how the trade-off manifests itself in a cross-section of firms. I finally argue that strong culture, in the sense of shared beliefs (Schein 1985, Van den Steen 2005a), may relax the trade-off (although it also comes at a cost).

Literature There are two other papers (in the economics literature) that deal, directly or indirectly, with the motivation-coordination trade-off: Athey and Roberts (2001) and Dessein, Garicano, and Gertner (2005).³ I will discuss these papers in detail in section 7, at which point it will be easier to compare the different mechanisms. As I will show there, the papers differ substantially from the current one, both in mechanism and in empirical predictions.

In the organization behavior literature, elements of this trade-off can already be found in Lawrence and Lorsch (1967). Not long after that important publication, however, the field of organization behavior shifted its focus from these structure/design issues towards more ‘behavioral’ issues such as social networks, influence, or emotion. One unfortunate consequence is that there is – to my knowledge – no relevant empirical work that studies the coordination-motivation trade-off.

The delegation/motivation effect is also related to the economic literature on delegation, in particular to Aghion and Tirole (1997) and Zábajník (2002). I discuss the difference with

²Roberts (2004) gives an informal discussion of this concept. The frontier indicates for a given level of resources spent (on motivation and coordination) how much motivation we can get for a desired level of coordination. A downward-sloping frontier implies a trade-off between motivation and coordination. He illustrates how this concept explains some important organizational changes and some implications for the ‘markets-firms’ trade-off.

³Friebel and Raith (2006) is also indirectly related. They study optimal horizontal integration when such integration enables resource allocation across the different activities. Within an integrated firm, the issues are similar to Dessein, Garicano, and Gertner (2005): to allocate resource optimally, the manager needs to extract information from the division managers, but doing so requires balanced incentives which conflict with the focused incentives that are required for optimal effort. In their model, however, coordination plays no role.

these papers – such as the empirical predictions on substitutes versus complements or the role that delegation plays – in detail in section 3.⁴

Finally, as I will discuss in section 6, two papers that are closely related to the current one also have implications for the motivation-coordination tradeoff. The first is Van den Steen (2005b), which shows that for a principal to have interpersonal authority over an agent, it may be necessary to minimize the agent’s pay-for-performance and other outcome-based incentives. The second is Van den Steen (2006), which studies the optimal allocation of control under differing priors (in the absence of coordination and incentive considerations). The delegation result also implicitly uses the endogenous overoptimism result of Van den Steen (2004b).

Contribution The contribution of this paper is threefold. It derives a new rationale for delegation, it shows that coordination problems that emerge from disagreement have to be solved with authority rather than incentives, and it shows that the combination of these two effects forces a trade-off between motivation and coordination. The observation that enforcement of centralized decisions may be non-monotone in the importance of coordination, is an interesting side-result.

The next section introduces the model. Sections 3 and 4 derive the motivation effect and coordination effect in partial equilibrium (with the agent’s incentives exogenously given). Section 5 combines these results and endogenizes incentives, thus deriving the motivation-coordination trade-off. Section 6 discusses other effects and potential solutions to the trade-off, section 7 compares to other papers, while section 8 concludes.

2 The Model

The model in this paper captures the common organizational setting in which employees must make decisions and exert effort to make a particular project succeed but, at the same time, the actions of different agents and of the principal need to be coordinated. A key question will then be whether the principal chooses to control the agent’s decisions or, instead, prefers to delegate them to the agent, and how that affects the agent’s choice of effort.

Formally, consider a principal P who employs an agent A for a project. As part of the project, A and P each will make a decision, denoted respectively D_A and D_P , from the set $\{X, Y\}$. Moreover, A also chooses whether to exert effort to execute his decision, i.e., he chooses $e \in \{0, 1\}$. Depending on all these actions, the project will ultimately either succeed or fail, generating an income of respectively 1 or 0. As mentioned earlier, the probability of success will, in particular, depend on 3 factors that I discuss now: the correctness of each player’s decision; whether the decisions are coordinated; and whether A exerted effort. First, a player’s decision will be correct if and only if it fits the state of the world $S \in \{x, y\}$. That

⁴Other papers on topics that are more indirectly related are Baker, Gibbons, and Murphy (1999), Dessein (2002), Hart and Holmstrom (2002), Prendergast (2002) Aghion, Dewatripont, and Rey (2004), Marino and Matsusaka (2004), and Marino, Matsusaka, and Zájbojník (2006). None of these papers, however, deal with the specific issues that are central to this paper.

state of the world is unknown, however, and each player i has his or her own subjective belief μ_i that the state is x . The players have differing priors, i.e., μ_A and μ_P may differ even though no player has private information about the state.⁵ I will discuss below how these beliefs get determined. Second, the players' decisions are coordinated if and only if $D_A = D_P$. Third, the agent's effort is a binary choice $e \in \{0, 1\}$ that imposes some private cost of effort on the agent A , as discussed below.

To specify the project's probability of success formally, let $d_i = I_{D_i=S}$ be the indicator function that the decision of person i is correct; $C = I_{D_A=D_P}$ the indicator function that the two decisions are identical ('Coordinated'); and e the indicator function whether the agent exerted effort. The probability of success Π of the project is then as follows:

$$\Pi = d_A + d_P - \beta_c c_c(1 - C) - \beta_e(1 - e)d_A$$

with $\beta_e, \beta_c \geq 0$ and $\beta_e + \beta_c \leq 1$. This function is a weighted sum of three terms, with β_c and β_e denoting the relative weights. The first term, $d_A + d_P$, is the basic payoff and simply depends on whether the respective decisions are correct or not. The second term, $-c_c(1 - C)$, captures the effect of coordination. If both players choose the same decision, then $C = 1$ and this term vanishes. If not, then the term imposes a 'coordination cost' c_c .⁶ The third term captures the effect of effort. If the agent exerts effort ($e = 1$), then this third term again vanishes, but if the agent does not exert effort then this term imposes a cost. As I will discuss later, the agent's effort is, in this specification, complementary to the decision being correct. The agent's private cost of effort will be $\beta_e c_e^2/2$. The reason for scaling the effort cost by β_e is that I want β_e to capture the importance of the effort component, without changing the cost-benefit of effort in itself.

The timing of the game, indicated in figure 1, is as follows. The principal first contracts with the agent on the outcome of the project. In particular, P offers A a wage w and a share α of the project revenue upon success. A accepts or rejects the offer, where rejection ends the game immediately. Furthermore, A is protected by limited liability and has an outside wage equal to zero. This will imply that in equilibrium $w = 0$. Once the players have contracted, $c_e \sim U[0, 1]$, $c_c \sim U[0, 1]$, and the μ_i are realized. The idea of having the costs and beliefs being drawn after the contract negotiation is that the contentious issues arise only after the project has been started, so that it is only at that time that it becomes clear which issues and thus which costs and beliefs are relevant.⁷ To keep the analysis transparent and tractable, I assume a very simple degenerate and independent distribution for the prior

⁵For a more extensive discussion of differing priors, see Morris (1995). Some papers by other authors that have used differing priors include Harrison and Kreps (1978), Morris (1994), Yildiz (2003), or Boot, Gopalan, and Thakor (2006). Differing priors do not contradict the economic paradigm: while rational agents should use Bayes' rule to update their prior with new information, nothing is said about those priors themselves, which are primitives of the model. In particular, absent any relevant information, agents have no rational basis to agree on a prior. Harsanyi (1968) observed that 'by the very nature of subjective probabilities, even if two individuals have exactly the same information and are at exactly the same high level of intelligence, they may very well assign different subjective probabilities to the very same events'.

⁶As will become clear below, c_c is a random variable. I also include β_c to transparently parameterize the importance of coordination.

⁷We could formalize this by assuming that there are many potential issues on which the players may disagree. Both players' beliefs on each of the issues are known, but it is revealed only at the end of period 1

1	2	3
Contracting	Actions	Payoff
a P offers A a contract (w, α) .	a P has the option to decide D_P and/or D_A .	a Project payoffs and costs are realized.
b A accepts or rejects. Upon rejection, the game is over and both get 0.	b Player i decides D_i (if D_i is undecided) and A chooses $e \in \{0, 1\}$.	b Contract terms (w, α) are executed.
c The costs c_e and c_c get drawn publicly.		
d The beliefs μ_i get drawn privately.		

Figure 1: Time line of the model

beliefs. In particular, for some given parameters $\nu_A, \nu_P \in (.5, 1)$, μ_i will equal either ν_i or $1 - \nu_i$, with equal probability. In other words, μ_i is drawn from a 2-point distribution with half its weight on ν_i and half on $1 - \nu_i$. It follows that each player will believe half the time that x is the most likely state, and half the time that y is the most likely state. Since the prior beliefs are independent draws, the players will agree only half the time, and disagree the other half. Moreover, each player always has the same confidence, ν_i , in the state that he considers most likely. These belief realizations are private information. In period 2a, the principal has the option to make any decisions she likes. If she does not decide D_A then she automatically delegates that decision to the agent. In period 2b, each player makes his decision if it wasn't made yet, and the agent also chooses his effort. The choices in period 2 are all public. In period 3, finally, the payoffs get realized and the contract is executed. The principal's utility is then $u_P = (1 - \alpha)\Pi - w$ and the agent's utility is $u_A = \alpha\Pi + w - \beta_e c_e^2/2$. In case of multiple equilibria, the players select the Pareto-dominant one, if one exists.

In what follows, I do the analysis in two steps. First, in sections 3 and 4, I consider motivation and coordination – separately – in the subgame starting in period 2, i.e., taking w, α, c_c, c_e , and the belief realizations as exogenously given. This case with (α, w) given builds intuition for the final result but is also important in its own right. In particular, in many instances the contract (α, w) is longer-term or determined by other factors, while the delegation and coordination decisions are part of daily decision making. In that case, this partial analysis is the right approach to derive empirical predictions. In section 5, I endogenize the contract and derive the full equilibrium and the trade-off.

3 Motivation and Delegation in Subgame Equilibrium

This section starts the analysis by studying the effect of delegation on the agent's motivation or effort. As mentioned earlier, the key building block is that – by revealed preference (applied to differing priors) – the agent has more confidence in his own decisions than in those of the manager. Delegation will thus increase the agent's confidence in the course of

which issue is relevant to this project. Letting c_e, c_c , and μ_i be drawn before the contract negotiations would qualitatively preserve the results of the paper, but makes some results more difficult to state and interpret.

action. When effort is a complement to making the right decision (so that effort is more useful when the decision is correct), then such higher confidence causes the agent to put in more effort.

I will first formalize this for the current model and then discuss how these results are affected by complements versus substitutes. To state the result formally, consider the subgame that starts in period 2, thus taking the contract (α, w) , the costs c_c and c_e , and the belief draws as given. Let ρ_i denote the belief (about any specified event) of player i at the end of period 2. To focus the argument, I also assume that $\beta_c = 0$ so that any coordination issues are excluded. The following proposition then compares the subgame equilibrium conditional on P delegating with the subgame equilibrium conditional on P not delegating, and shows that effort and confidence are higher under delegation.⁸

Proposition 1a *For any given $(\alpha, w, c_c, c_e, \mu_A, \mu_P)$, both $\rho_A(D_A = S)$ and e are (weakly, and for some values strictly) higher when P delegates D_A than when P makes the decision herself.*

Proof : Consider first the agent's effort decision. Note that A either observes D_A (when P decides D_A in period 2a) or decides D_A himself, so that he always knows D_A when he chooses e . Let Z_i denote the optimal action choice according to player i . The agent exerts effort iff $\alpha\beta_e E_A[d_A] \geq \beta_e c_e^2/2$ or $\sqrt{2\alpha E_A[d_A]} \geq c_e$. Since D_P does not affect A 's effort choice, P will always choose $D_P = Z_P$ (in 2a or 2b, which makes no difference).

Let $\underline{c} = \sqrt{2\alpha(1-\nu_A)}$ and $\bar{c} = \sqrt{2\alpha\nu_A}$. When $c_e \notin [\underline{c}, \bar{c}]$, the choice of D_A does not affect e . It follows that P would choose $D_A = Z_P$ while A would choose $D_A = Z_A$. It further follows that $\rho_A(D_A = S)$ equals ν_A under delegation and $(1 - \nu_A)$ when P does not delegate. The proposition thus holds when $c_e \notin [\underline{c}, \bar{c}]$.

When $c_e \in [\underline{c}, \bar{c}]$ then $e = 1$ iff $D_A = Z_A$. When P delegates, then A will always choose $D_A = Z_A$ (so that $\rho_A(D_A = S) = \nu_A$) and $e = 1$. When P does not delegate then (since she does not know Z_A) P always chooses Z_P . When μ_A and μ_P are such that $D_A = Z_A$ then $e = 1$ and $\rho_A(D_A = S) = \nu_A$ like in the delegation case, else $e = 0$ and $\rho_A(D_A = S) = (1 - \nu_A)$ which are both strictly smaller than in the delegation case. This proves the proposition. ■

Note that this result would not hold, as such, if the players had a common prior but different signals: unless the agent has a more informative signal – which I do *not* assume here – the agent realizes that his information is no better than that of his principal; with a common prior, he will thus – in expectation – have at least as much confidence in a decision by his principal. To see this in a different way, note that this result is essentially the same as the overoptimism result of Van den Steen (2004b).

This result suggests that delegation should increase in the importance of effort. The following proposition confirms that intuition.

Proposition 1b *For any (α, w) and $(\mu_A, \mu_P, \beta_c, c_c, c_e)$, there exists a $\hat{\beta} \in [-\infty, \infty]$ such that P delegates iff $\beta_e \geq \hat{\beta}$.*

⁸Technically, it is thus as if I split stage 2a in two steps: the decision to delegate and the potential choice of D_P (and D_A if applicable), and then consider the effects of the delegation decision.

Proof : Let Z_i denote the action that player i considers best. The agents exerts effort iff $\alpha\beta_e E_A[d_A] \geq \beta_e c_e^2/2$ or $\sqrt{2\alpha E_A[d_A]} \geq c_e$, so let again $\underline{c} = \sqrt{2\alpha(1-\nu_A)}$ and $\bar{c} = \sqrt{2\alpha\nu_A}$. If $\underline{c} \geq c_e$ then A always exerts effort, if $\bar{c} \geq c_e \geq \underline{c}$ then A exerts effort iff $D_A = Z_A$, and if $c_e \geq \bar{c}$ then A never exerts effort. Since these 3 cases do not depend on β_e , I can show the result case by case.

If $\underline{c} \geq c_e$, A always exerts effort, so that P doesn't gain from allowing $D_A = Z_A$. She will therefore make sure that $D_A = D_P = Z_P$ by centralizing the decision whenever $\underline{c} \geq c_e$ (i.e., by choosing D_A in 2a). The proposition then holds for $\hat{\beta} = \infty$.

The case with $\bar{c} \leq c_e$ is analogous but now with A never exerting effort.

If, finally, $\bar{c} \geq c_e \geq \underline{c}$, so that A exerts effort iff $D_A = Z_A$, then P has the following choices:

- a. $D_A = D_P = Z_P$, but $e = 0$ when $Z_A \neq Z_P$, so that $U_P = (1 - \alpha) \left(2\nu_P - \frac{\beta_e}{2} \nu_P \right)$.
- b. $D_P = Z_P$, $D_A = Z_A$, and $e = 1$, so $U_P = (1 - \alpha) \left(\nu_P + \frac{\nu_P + (1 - \nu_P)}{2} \right)$.

Note that the second outcome obtains when P does not make any decisions in period 2a, so that A follows her prior Z_A . (In particular, this excludes A trying to coordinate. Other equilibria are possible, e.g. with both players always choosing X , but are Pareto-dominated.)

In this case delegation is optimal iff case b is optimal. So I need to show that there exists a $\hat{\beta}$ such that case b is optimal iff $\beta_e \geq \hat{\beta}$. Some algebra shows that this is indeed true with $\hat{\beta} = \frac{2\nu_P - 1}{\nu_P}$. ■

There is something remarkable about this result : the principal delegates even though she knows that delegation can only make the decision worse. Moreover, she would not overturn a decision that she believes is wrong even if she could do so. In fact, instead of delegating, the principal could also ask her employees to suggest a course of action and then rubberstamp that decision (even if she actually believes it is wrong, which is in contrast to rubberstamping in Aghion and Tirole (1997)'s P-formal authority model where the principal only rubberstamps decisions that she infers to be optimal given her information). While this may sound a bit surprising, it is actually not at all unusual in organizations for a manager to allow her employees to follow a course of action that she believes to be inferior but that she knows 'fires up the troops'.

An important factor in this mechanism is – as mentioned above – the fact that effort and correct decisions are complements in the specification of the probability of success Π : Π has increasing differences in e and d_A since $\frac{\partial \Pi(e, d_A=1)}{\partial e} \geq \frac{\partial \Pi(e, d_A=0)}{\partial e}$ (Milgrom and Roberts 1990, Milgrom and Roberts 1994). In other words, effort is more useful when the decision is correct than when the decision is wrong. The prototypical case of such complementarity is the situation where effort is necessary to implement a decision. Implementing a wrong decision is not very useful so that implementation effort on a wrong decision is more or less wasted. Effort to implement a correct decision, on the other hand, is very useful.

The opposite case would be when effort and correct decision are substitutes, i.e., when the inequality runs in the other way and effort is thus *more* useful when the decision is *wrong*. It is more difficult to find clean examples of this. One situation that tends to come to mind is a situation where effort can make up for a wrong decision, although this case turns out to be less clear-cut than it may seem. Imagine, for example, that the project is a success if and only if it achieves a specific level of quality, and that effort and decision quality are additive.

In this case, there is usually a range of values where effort and decisions are substitutes, but (importantly) there is also usually a range where they are complements.⁹

In the case that effort and correct decisions are substitutes, the result is exactly the opposite: delegation will actually lead to lower effort levels by the agent. Appendix B shows this result formally and studies the implications for delegation.

Although the issue whether decision and effort are complements or substitutes is an empirical one, the above examples and informal observations suggest that complementary effort is more common and more important than substitute effort. That is the reason for focusing on that case.

I will now argue that this theory of delegation differs both in terms of predictions and in terms of underlying mechanisms from Aghion and Tirole (1997) and Zábajník (2002).

In Aghion and Tirole (1997), agent and principal get (initially unknown) private benefits from alternative courses of action, and can spend effort on learning these private payoffs. The role of delegation – or A-formal authority as they also refer to it – is to give the agent maximal returns from – and thus incentives for – collecting information, by allowing him to choose his most preferred action. Since effort is an input to making decisions in their model, effort and decisions are neither complements nor substitutes so that they have no predictions regarding this distinction. Second, information collection by the principal – which is absent from the current model – plays a crucial role in theirs: without such information collection, delegation would not matter since the principal would anyways always follow the agent’s advice. Third, commitment (to delegation) is essential in Aghion and Tirole (1997): if the principal were able to overturn the agent’s decision whenever she finds out what his optimal action is, then she would do so, and the effect of delegation would be eliminated. In the current paper, on the contrary, the principal would not overturn the agent’s decision, even if she could. Finally, the papers’ mechanisms are very different in the following sense: in Aghion and Tirole (1997), the agent put in effort *in order to* select (in the future) an attractive action, while here the agent put in effort *because* an attractive action was selected (in the past).

In Zábajník (2002), agent and principal each get a private *signal* about which action is most likely to succeed. Since ordering the agent what to do reveals the principal’s signal, delegation is necessary if the principal wants to hide her signal, and she may want to do so when hiding her signal increases the agent’s effort. The current paper shares with Zábajník (2002) the idea that – with complements – the agent will spend more effort if he has more confidence in the decision and that delegation may be used to affect the agent’s confidence. The papers, however, differ substantially in the effect and role of delegation and, as a consequence, in their predictions. In Zábajník (2002), the agent may actually have more confidence under centralization than under decentralization. This will, in particular, be the case when his signal agrees with that of the principal. Since his signal is more likely to agree than to disagree with that of the principal, it is – in Zábajník (2002) – actually more likely

⁹For an example, let the outcome function R be an additive function of the decision indicator d and the effort level e , i.e., $R = d + e$ with $d, e \in \{0, 1\}$. Assume that the project is a success with payoff 1 if and only if $R \geq \bar{R}$, and give payoff 0 otherwise. In this case, effort compensates for bad decisions. Note now that e and d are *substitutes* when $\bar{R} < 1$, but they are *complements* when $\bar{R} > 1$.

that the agent is more confident under centralization than under decentralization, than the other way around. Even when taking the strength of beliefs into account, it is straightforward to show that the agent's expected confidence is higher under delegation only if his signal is stronger than that of the principal. In the current paper, on the contrary, the agent *always* has more confidence in the decisions under delegation – by revealed preference – and will thus always spend more effort in the case of complements. So while in Zábojník (2002) delegation under complements may either increase or decrease the agent's confidence and effort, the current paper makes a clear prediction that effort will increase under delegation when effort and correct decisions are complements. Zábojník (2002) also shows that delegation can be optimal not only under complements but also under substitutes. The latter is never the case in the current paper.

4 Coordination in Subgame Equilibrium

Consider now the issue of coordination. Since coordination is a special case of externalities, two ways to deal with coordination issues come immediately to mind.¹⁰ The first is to use incentives. The idea here is to make the agent internalize the externality he causes by not coordinating with the other, and thus to make it in his interest to coordinate (at least when coordination is efficient). This incentive approach plays, for example, an important role in both Athey and Roberts (2001) and Dessein, Garicano, and Gertner (2005). In both cases, the agent's incentives will become more broad-based or more balanced as coordination becomes more important. The second way to get coordination is by using authority. In particular, when the principal can tell the agent what to do, then it is as if all decisions are made by one person and thus automatically coordinated. This suggests that centralization should increase when coordination becomes more important.

The main result of this section is that the incentive solution to coordination often doesn't work, or works less well, when differing priors (rather than private benefits) are the source of the coordination problems. The reason is that giving the agent more residual income not only makes him care more about coordination but also increases his incentives to follow his own beliefs, even if that means losing coordination. In the model of this paper, these two effects exactly cancel each other out so that incentives don't work at all to solve coordination problems. To better illuminate the role of differing priors, I contrast the differing priors model with an analogous private benefits model and get a very different conclusion: while residual income allocation has no effect on coordination in the differing priors model, it always allows to achieve efficient coordination in the private benefits model. Although this is just one comparison (though an important one), and thus does not allow us to conclude that incentives never work with differing priors and/or always work with private benefits, the contrast does provide some clear clues as to why residual income performs worse in solving the coordination problem in the differing priors model than in the private benefits model. The main implication of this analysis is that organizations have to rely more heavily on authority to solve coordination problems when they are caused by differing priors.

¹⁰I focus here on coordination issues caused by conflicting benefits or beliefs, and thus disregard awareness, equilibrium selection, and information issues, which are also important sources of coordination problems.

To study this effect formally, consider the model in section 2. As in section 3, consider the subgame starting in period 2, and assume now that $\beta_e = 0$ to focus completely on coordination. While section 3 compared the equilibrium conditional on centralization and decentralization, I will focus here completely on the case that P decides to delegate. This effectively eliminates authority for now, and thus allows me to study transparently what can or cannot be achieved (in terms of coordination) by appropriately allocating residual income.

Note that if the players could contract on the actions and the income rights (and a transfer) then they would always agree to coordinate. In other words, joint utility maximization always requires coordination. Absent the ability to contract on actions, the players could try to achieve coordination just by using incentives. In particular, they could try to allocate the income shares so that each player internalizes his effect on the coordination cost, $\beta_c c_c(1 - C)$, in a way that makes the players coordinate. The following proposition says that this is impossible, as long as α is not 0 or 1. In particular, it implies that whether the players end up coordinating or not is completely independent of the distribution of income α .

Proposition 2a *The players coordinate if and only if $(2\nu_A - 1) \leq \beta_c c_c$. This condition is independent of α , as long as $\alpha \in (0, 1)$.*

Proof : To get coordination, the agent must be willing to forgo his preferred course of action. The agent, with share α_A of the project revenue, is willing to do so if $\alpha_A(1 - \nu_A) \geq \alpha_A(\nu_A - \beta_c c_c)$ or $\beta_c c_c \geq 2\nu_A - 1$. This implies the proposition. ■

To clarify what is happening, it is useful to contrast this with an analogous model with private benefits. In particular, consider a standard private benefits model in which the common project generates $1 - \beta_c c_c(1 - C)$ (which gets distributed according to α_A and α_P), while player i also gets a private benefit $B_i \geq 0$ from choosing his or her preferred action. Each player's preferred action is randomly and independently determined, with X and Y being equally likely. Note that, for a given set of differing priors and for *fixed* α_i , this private benefits model is equivalent to the differing priors model with $B_i = \alpha_i(\nu_i - \frac{1}{2})$. The following proposition now says that the coordination problem can always be solved by an appropriate choice of α .¹¹

Proposition 2b *Whenever it is efficient for A to coordinate with P , there exists an α that implements such coordination (under delegation).*

Proof : Note that P , not knowing Z_A , will always choose Z_P (in any equilibrium that is not Pareto-dominated). It is then efficient for A to always coordinate with P if $\beta_c c_c \geq B_A$, which he will do if $\alpha_A \beta_c c_c \geq B_A$, which can always be satisfied. This proves the proposition. ■

To see the intuition behind these contrasting results, consider what happens in the case of private benefits. Each player's action choice exerts an externality on the other player through its impact on the project revenue. Shifting project revenue to a player has two effects: it makes that player internalize the externality and therefore make a more efficient choice, and it reduces the externality on the other player. An important equivalent intuition

¹¹For the statement of the proposition, note that, given the structure of the game, A can coordinate its action with P (by following P 's lead when P chooses in 2a) but not the other way around.

is that allocating more of the project revenue to a player reduces the relative importance of his private benefits and thus makes his actions more efficient.

In the differing priors model, on the contrary and as mentioned earlier, allocating more residual income to a player makes that player care more, not only about his miscoordination externality, but also about the course of action he ends up taking, and these two effects exactly cancel each other out. Another way to see this is that with differing priors, the residual income *is* the embodiment of the private benefits. As a consequence, shifting residual income simultaneously changes the corresponding private benefits. And in this case, the change in corresponding private benefits goes exactly opposite to what the parties desire to achieve.

While the result may seem quite trivial in the current context (although it actually holds in much more generality), it does indicate a significant difference between differing priors and private benefits. It also suggests that the focus of economics on private benefits may bias conclusions in the direction of incentives, away from more direct forms of authority.

The second result of this section is that the principal will only enforce, or need to enforce, her decisions at *intermediate* costs of miscoordination. The reason is that when miscoordination is very damaging to the project then the agent has independent incentives to coordinate (if the agent somehow cares about the outcome), which then reduces the need to enforce authority. At low levels of miscoordination costs, this independent incentive is insufficient to cause effective coordination, so that it is necessary to enforce the principal's decisions to get coordination. But low levels of miscoordination costs also mean that there is little to gain from coordination, so that the gain from enforcement is low. At the other extreme, when miscoordination costs are very high, the incentives for autonomous coordination become sufficient to cause effective coordination. In the differing priors model above, for example, the players coordinated autonomously if $\beta_c c_c \geq (2\nu_A - 1)$. High levels of miscoordination costs c_c then reduce the need for enforcing the principal's decisions. Overall, the need for enforcement is thus indeed highest at intermediate levels of $\beta_c c_c$.

To see simultaneously both results – the use of authority at high levels of $\beta_c c_c$ and the use of enforcement at intermediate levels of $\beta_c c_c$ – consider the model of section 2 with probability of success

$$\Pi = d_A + d_P - \beta_c c_c (1 - C) - \beta_e (1 - e) d_A$$

where $C = I_{D_A=D_P}$ is the indicator function that D_A and D_P are coordinated ('Coordinated'). Let $\gamma_c = \beta_c c_c$; let \hat{J}_A denote the person who optimally decides on D_A from the perspective of the principal; and let F be the indicator function that P needs to enforce her decisions (i.e., that A would disobey P if he had the chance). The following proposition says that – for exogenously given α – increasing $\gamma_c = \beta_c c_c$ leads to more coordination ($C = 1$) and less decentralization ($\hat{J}_A = P$). Enforcement of P 's decisions ($F = 1$), however, is necessary only at intermediate levels of γ_c . Moreover, all the cutoff levels are independent of α , which means that incentives are completely ineffective to achieve coordination.

Proposition 3 *For any $(\nu_A, \nu_P, \alpha, \beta_e, c_e)$, there exist $\gamma_1, \gamma_2, \gamma_3, \gamma_4$ (which may sometimes be ∞) such that*

- $C = 1$ iff $\gamma_c \geq \gamma_1$
- $\hat{J}_A = P$ iff $\gamma_c \geq \gamma_2$
- $F = 1$ iff $\gamma_3 \leq \gamma_c < \gamma_4$

The γ_1 , γ_2 , γ_3 , and γ_4 are independent of α .

Proof : As before, it will suffice to show this for each of the following (mutually exclusive, collectively exhaustive) cases:

1. $c_e \geq \sqrt{2\alpha\nu_A}$ so that A never exerts effort,
2. $c_e \leq \sqrt{2\alpha(1-\nu_A)}$ so that A always exerts effort, and
3. $\sqrt{2\alpha\nu_A} \geq c_e \geq \sqrt{2\alpha(1-\nu_A)}$ so that A exerts effort iff $D_A = Z_A$.

In case 1 (where $e = 0$), P will always make sure that $D_A = Z_P$ and $C = 1$, so that $\gamma_1 = 0$ and $\gamma_2 = 0$. Enforcement will be necessary ($F = 1$) if (and only if) A prefers Z_A rather than Z_P , which is when $(1 - \beta_e)\nu_A - \beta_c c_c \geq (1 - \beta_e)(1 - \nu_A)$ or $(1 - \beta_e)(2\nu_A - 1) \geq \beta_c c_c$ so that $\gamma_3 = 0$ and $\gamma_4 = (1 - \beta_e)(2\nu_A - 1)$. Case 2 (where $e = 1$) is completely analogous, except that $\gamma_4 = 2\nu_A - 1$. Consider now case 3 (where $e = 1$ iff $D_A = Z_A$). The principal has the following choices:

- a. $D_A = D_P = Z_P$, but $e = 0$ when $Z_A \neq Z_P$: $U_P = (1 - \alpha)(2 - \frac{\beta_e}{2})\nu_P$
- b. $D_P = Z_P$, $D_A = Z_A$, and $e = 1$: $U_P = (1 - \alpha)(\nu_P + \frac{\nu_P + (1 - \nu_P) - \beta_e c_c}{2}) = (1 - \alpha)(\nu_P + \frac{1 - \gamma_e}{2})$.

where the second case obtains when P does not make any decisions in period 2a. (Other equilibria are again Pareto-dominated.) Note that case 3a dominates case 3b if and only if $(2 - \frac{\beta_e}{2})\nu_P \geq (\nu_P + \frac{1 - \gamma_e}{2})$ or $\gamma_c \geq 1 - (2 - \beta_e)\nu_P = \beta_e \nu_P - (2\nu_P - 1) = \tilde{\gamma}$. With respect to enforcement within case 3a, note that A strictly prefers Z_A iff

$$\alpha((1 - \nu_A) + \nu_A - \gamma_c) - \beta_e c_e^2 / 2 > \alpha((1 - \nu_A) + (1 - \beta_e)(1 - \nu_A))$$

or $\gamma_c < \hat{\gamma} = 2\nu_A - 1 + \beta_e(1 - \nu_A) - \frac{\beta_e c_e^2}{2\alpha}$ so that enforcement is necessary in case 3a only if $\gamma_c < \hat{\gamma}$. To finish the proof for case 3, note that if $\beta_e \leq \frac{(2\nu_P - 1)}{\nu_P}$ then $\tilde{\gamma} \leq 0$ and 3a dominates 3b, so that $\gamma_1 = \gamma_2 = 0$. Moreover, $\gamma_3 = 0$ and $\gamma_4 = \hat{\gamma}$. If $\frac{(2\nu_P - 1)}{\nu_P} \leq \beta_e$, then 3a dominates 3b iff $\gamma_c \geq \tilde{\gamma} \geq 0$, so $\gamma_1 = \gamma_2 = \tilde{\gamma}$. Enforcement is needed iff $\gamma_c \in [\min(\tilde{\gamma}, \hat{\gamma}), \hat{\gamma}]$. This proves the proposition. ■

While this result says that no enforcement of authority will be necessary when coordination is very important (since the players will self-coordinate), there are a few important caveats to this result. First of all, it does assume and require that the players all care about the overall project outcome. Second, the players have to find a way to coordinate on the same action, which is non-trivial since there are typically multiple equilibria. In the model, the latter issue was absent since the principal chose first. The absence of such sequencing would make coordination more difficult. Finally, when coordination does happen, the principal will want to make sure that they coordinate on the action that she believes is best. If she cannot impose this through choosing first, then she has even more reasons to enforce her decisions. This requires further research.

5 Putting it all together: Coordination versus Motivation

From an organization design perspective, one of the key implications of the preceding analysis is that the need to allocate authority induces a trade-off between motivation and coordination. In particular, in the typical case that effort and decisions are complements, centralized decision-making gives strong coordination but weak motivation, while decentralized decision-making gives weak coordination but strong motivation. Assigning decision rights thus forces a choice between motivation and coordination.

One way to think about this trade-off is in terms of a motivation-coordination ‘possibility frontier’ (Roberts 2004). Such possibility frontier shows the maximum degree of coordination as a function of the desired level of motivation for a given amount of resources spent. A down-sloping possibility frontier indicates a trade-off between motivation and coordination.

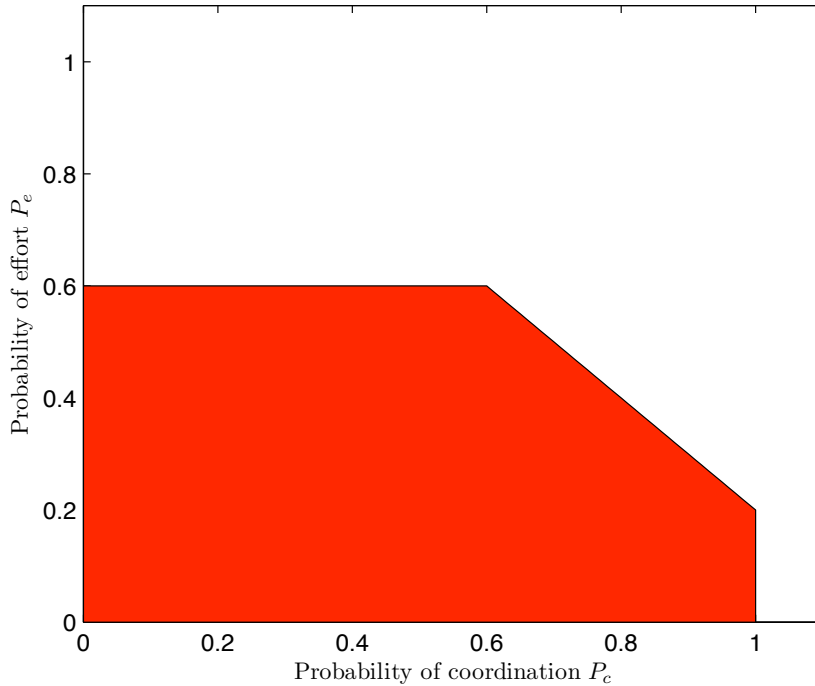


Figure 2: The within-firm tradeoff between motivation and coordination. $\nu_A = .9, \alpha = .2$

For the model of section 2, the possibility frontier can be derived directly from the analysis of the preceding sections. In particular, in the context of that model, the frontier captures the maximum probability of coordination as a function of the desired probability of agent-effort, for a given level of agent-incentives α . One such frontier for the model is represented in figure 2. Note that, since the frontier just represents possibilities without reference to their relative benefits, this graph is independent of the importance of effort or coordination. The relationship of this frontier to the equilibrium outcome is as follows. For a given frontier, i.e.,

for a given α , the principal essentially picks a motivation-coordination point on the frontier (by his choice of delegation). The choice of α in the first stage determines from which frontier the principal can choose. Note also that I define the ‘probability of coordination’ here to be the probability that the principal’s actions are such that there will always be coordination.¹²

The fact that the possibility frontier is downward sloping can be derived formally. Let the function $\overline{P}_c(P_e)$ denote the maximum probability of coordination if the desired probability of effort is P_e . The following proposition essentially combines the earlier delegation and coordination results.

Proposition 4 *For any $(\nu_A, \nu_P, \alpha, w)$, $\overline{P}_c(P_e)$ decreases in P_e .*

Proof : Remember that

1. If $c_e \leq \sqrt{2\alpha(1-\nu_A)}$ then A will always exert effort, and P can always ensure coordination.
2. If $c_e \geq \sqrt{2\alpha\nu_A}$ then A will never exert effort, so P can again always ensure coordination without affecting effort.
3. If $\sqrt{2\alpha(1-\nu_A)} \leq c_e \leq \sqrt{2\alpha\nu_A}$ then A will exert effort if and only if $D_A = Z_A$. By randomizing between Z_A and Z_P , P can choose any probability of coordination P_c . But the probability of effort will necessarily be $P_e = 1 - P_c$.

Consider first the case that $\sqrt{2\alpha(1-\nu_A)} < 1$. For $P_e \leq \sqrt{2\alpha(1-\nu_A)}$, we then have $\overline{P}_c = 1$. For $\sqrt{2\alpha(1-\nu_A)} < P_e \leq \min(\sqrt{2\alpha\nu_A}, 1)$, \overline{P}_c will be a strictly decreasing function with slope -1 . For $P_e > \sqrt{2\alpha\nu_A}$, \overline{P}_c drops to zero, since these values of P_e are impossible. In the case that $\sqrt{2\alpha(1-\nu_A)} \geq 1$, the $\overline{P}_c = 1$ for all values of P_e . This concludes the proposition. ■

This perspective on the motivation-coordination trade-off focuses on within-firm comparisons. A different way to think about the trade-off is to look at a population of firms and see whether motivation and coordination are negatively correlated across firms. The following proposition does that, and more. It shows that in firms where effort is more important and/or coordination is less important, delegation will be high, effort will be high, and coordination will be low, and vice versa. It also shows that, as a consequence, there will be a negative tradeoff between effort and coordination in the population. Let P_d , P_c and P_e denote respectively the equilibrium probability of delegation, coordination, and effort.

Proposition 5 *For any ν_A, ν_P ,*

- P_d increases in β_e and decreases in β_c
- P_c decreases in β_e and increases in β_c ,
- P_e decreases in β_c and increases in β_e ,

¹²When the principal delegates, the parties will obviously also happen to coordinate from time to time, but this is pure coincidence rather than on purpose. Using the wider definition of ‘probability of coordination’ to be the probability that there happens to be ex-post coordination, simply requires a transformation of variable that preserves all results and graphs (up to the rescaling).

- For a given β_e and for $\beta_c \sim F$ for any F with $\text{supp } F \subset [0, 1 - \beta_e]$, P_c decreases in P_e .
- For a given β_c and for $\beta_e \sim F$ for any F with $\text{supp } F \subset [0, 1 - \beta_c]$, P_c decreases in P_e .
- For $\beta_e = k - \beta_c$, with $k \in [0, 1]$, and $\beta_c \sim F$, with $\text{supp } F \subset [0, k]$, P_c decreases in P_e .

Proof : The proof is in appendix. ■

Figure 3 represents this graphically. In particular, it depicts the probabilities of effort and coordination for 20,000 ‘firms’ for which (β_e, β_c) were randomly drawn from the $[(0, 0), (1, 0), (0, 1)]$ triangle. Note that this is now *not* a possibility frontier any more, but an equilibrium outcome. It is clear that there is a strong trade-off between motivation and coordination across firms.¹³

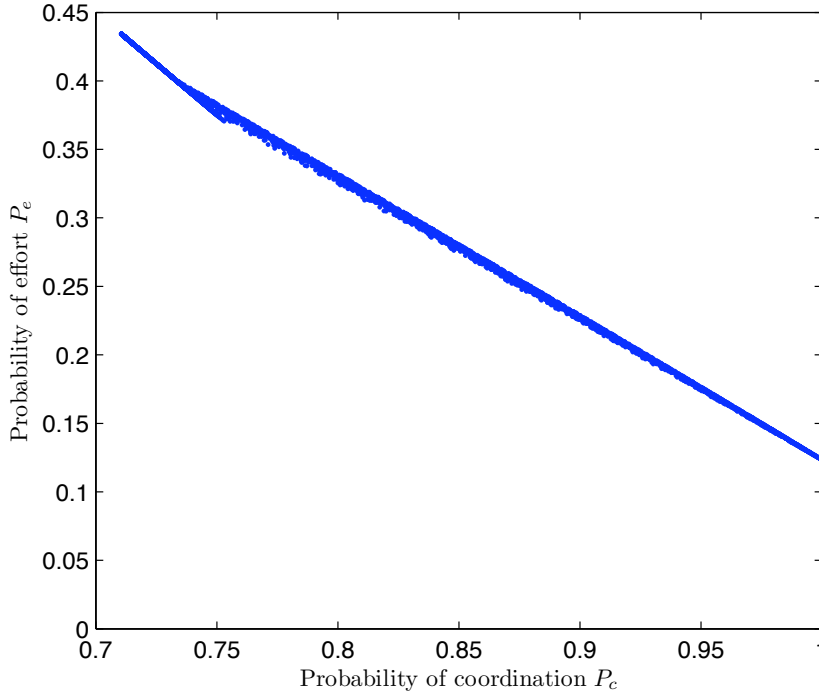


Figure 3: The across-firms tradeoff between motivation and coordination. $\nu_A = \nu_P = .9, n = 20,000$. For 20,000 firms, the (β_e, β_c) were randomly drawn. The graph represents the probabilities of coordination and effort for each of these firms.

¹³This can potentially also be interpreted as within-firm comparisons: we could imagine that a firm is faced with 20,000 projects that each have a different weight on motivation and coordination (i.e., different β_e and β_c). The data then represent the motivation/coordination equilibrium outcomes for each of these project. However, the ‘across-firm’ interpretation seems to fit better.

6 Discussion

6.1 Additional Effects of Differing Priors on Motivation and Coordination

An important simplifying assumption in this paper is that the principal can simply choose whether to centralize or decentralize the decision D_A , at no cost. However, nearly any decision must get executed by an agent, who can – at least in principle – choose not to follow the (centralized) decision. In some cases, this issue is of little concern since the agents have no reason to deviate from the centralized decision and since the principal has simple means for enforcing her decision. When, for example, a dean raises a faculty's salary, the school's administrative staff is unlikely to refuse to implement that decision. If so, we can simply assume that decision rights get allocated by contract or by fiat. In important other cases, however, an agent may have reasons to disobey the principal and enforcing obedience may then be more problematic. When the same dean decides how his faculty should teach their classes, he may have a much more difficult time enforcing obedience. In that case, ensuring centralization may be costly and may have important implications in and of itself.

Van den Steen (2005b) shows how this issue of compliance may introduce an additional effect to motivation-coordination trade-off. In particular, strong incentives may give the agent more reason to disobey his principal's orders when the two of them disagree on the right course of action. This strengthens obviously the trade-off between motivation and coordination: to get the agent to exert more effort, the principal needs to give more incentives, but this reduces his control over the agent and thus reduces the coordination that is possible.

There is one further effect of differing priors that indirectly affects the trade-off between motivation and coordination. Van den Steen (2006) shows that shifting the residual income to one person makes it efficient to also allocate more control rights to that person, and vice versa. This is due to a combination of two effects. On the one hand, shifting control rights to a person makes that person value the income rights higher, by revealed preference. On the other hand, shifting income rights to a person makes that person value the control rights higher, since they affect his utility more.¹⁴ This co-location of authority and income rights implies that giving a person incentives (to increase effort) will make it more attractive to also delegate that person more decision rights, but that will lead to less coordination. Although the effect is indirect, it is another force in the motivation-coordination tradeoff. The assumption of limited liability for the agent eliminated this effect from the analysis.

6.2 Is the trade-off unavoidable?

Given the importance of this trade-off, does the theory suggest any way to get around it? And if the theory does suggest such a way, why don't all firms use it, and so why would we

¹⁴As Van den Steen (2006) shows, this intuitive mechanism requires differing priors and does not hold in an analogous model with common priors but private benefits. First, with common priors all players value an income stream identically, which eliminates the first effect. Second, private benefits and residual income from a project may require conflicting decisions, in which case a player may value control *less* when his private benefits become more important.

still observe the tradeoff?

The theory actually *does* suggest how to eliminate, or at least mitigate, the trade-off: hire agents who agree with the principal. Increasing the degree of agreement between principal and agent has a double effect. On the one hand, the agent will be more motivated when decisions are centralized since he often agrees with the principal's decision and thus expects a high return on his effort. On the other hand, delegation leads to fewer coordination problems since the agent will often choose the same course of action as the principal.

The idea that a high degree of homogeneity allows to combine high coordination with strong motivation is in line with some of the ideas in the management literature. In particular, 'corporate culture' has often been interpreted as shared beliefs or shared values (Schein 1985, Van den Steen 2005a) and the ability to motivate people in a coordinated way has been mentioned as one of its important advantages (Kotter and Heskett 1992).

So why wouldn't all firms do this? The answer to this question is two-sided. On the one hand, firms definitely do this, to some degree. In particular, firms sort explicitly in their hiring process for employees who 'fit', and fit is in part about the employees' beliefs and values. Employees also self-sort: employees who get forced to follow a course of action that they believe will lead to failure may simply quit when they care about the outcome. Both sorting and self-sorting, however, are difficult and expensive. Self-sorting is in essence turnover, which causes an immediate destruction of firm specific human capital and of organizational capital. Sorting by the firm is hindered by the fact that many beliefs are implicit and moreover easy to misrepresent. Finally, shared beliefs and values also have negative effects, e.g. by reducing the incentives to collect information or to communicate (Landier, Sraer, and Thesmar 2006, Van den Steen 2004a).

Overall, only firms who really need simultaneously high levels of coordination and high levels of motivation, and who can live with the downsides of homogeneity, should follow this path. As a consequence, the trade-off will remain even though solutions are available.

7 Comparison to other papers on the motivation vs. coordination trade-off

As mentioned in the introduction, there are two other papers that deal (directly or indirectly) with the motivation-coordination trade-off.

To my knowledge, the first formal economics paper on the trade-off between motivation and coordination is Athey and Roberts (2001), who study the conflict between effort and correct decisions in the presence of externalities, which includes coordination as a special case. Their argument is as follows. Imagine a situation where an agent has to spend effort that increases his own output, but the agent also has to make a decision that affects both his own output and that of others. If the firm wants to raise the agent's effort, it needs to increase the pay-for-performance on the agent's own output. However, in order to get optimal decisions in the presence of externalities, equal weight should be put on all the output-components that are affected by that decision, i.e., incentives should be balanced. Ideally the firm would thus also want to raise the agent's pay-for-performance on the others'

output. But doing so is costly since it exposes the agent to more risk. As a consequence, increasing effort will in equilibrium lead to more distorted decisions.

Dessein, Garicano, and Gertner (2005) study how organizing a firm along functional or product lines affects the implementation of synergies, which again includes coordination as a special case. The central result (from the perspective of the current paper) is again that coordination requires balanced incentives, and thus reduces effort, with the cost of giving incentives now coming from the budget balance constraint. In their paper, however, there are two mechanisms that drive the need for balanced incentives. While the first mechanism is similar to that in Athey and Roberts (2001), they also have the interesting new result that raising pay-for-performance on the agent's own output will reduce communication about potential externalities. This communication effect thus introduces a second important trade-off. Finally, their analysis also shows that changing decision structures without simultaneously changing incentives may be futile, and illustrate that point with applications.

Both these papers are very different from the current one. One key distinction is that in both Athey and Roberts (2001) and Dessein, Garicano, and Gertner (2005), the allocation of control has no direct effect (other than through the intensity of incentives) on the agent's effort or motivation. In other words, after controlling for incentives, delegation does not play a role in the agent's motivation and the trade-off disappears. This distinguishes these two models from this paper's both in terms of mechanisms and in terms of empirical implications. With respect to coordination, both papers rely to a large extent on the externality-internalizing effects of residual income, which I show explicitly to be completely ineffective in this paper. Furthermore, there are also obvious differences in the underlying mechanisms such as the role of private information versus differing priors.

8 Conclusion

This paper studied how open disagreement affects the delegation/centralization decision when the firm cares about both motivation and coordination. I first derived a new rationale for delegation: delegation increases motivation when effort and correct decisions are complements since the agent thinks that his own decisions are better than those of the principal. A need for implementation effort will thus lead to more decentralization. The opposite is true when effort and decisions are substitutes.

I then turned to coordination and showed that coordination problems caused by differing priors require more reliance on authority (as opposed to incentives) than coordination problems caused by private benefits. The reason here is that while incentives make the agent care more about coordination, that effect gets counter-acted by the fact that incentives give the agent more reasons to follow his own beliefs. In this paper, these two effects exactly cancelled each other out. I also showed that the principal will (need to) enforce her decisions only at intermediate levels of the need for coordination.

The combination of these results implied a trade-off between motivation and coordination. This trade-off is one of the key challenges in organization design.

A Proofs

Proof of Proposition 5: Remember the cases 1, 2, 3a, and 3b of the proof of proposition 3. Let $\tilde{\gamma}$ again be such that 3a dominates 3b iff $\gamma_c \geq \tilde{\gamma}$, let $\tilde{c} = \frac{\tilde{\gamma}}{\beta_c}$ or

$$\tilde{c} = \frac{1 - (2 - \beta_e)\nu_P}{\beta_c} = \frac{1 - 2\nu_P + \beta_e\nu_P}{\beta_c}$$

and let \check{c} be its restriction to $[0, 1]$, i.e., $\check{c} = \max(0, \min(1, \tilde{c}))$. We then have that

$$\begin{aligned} P_d &= \left(\sqrt{2\alpha\nu_A} - \sqrt{2\alpha(1 - \nu_A)} \right) \check{c} = \sqrt{2\alpha} \left(\sqrt{\nu_A} - \sqrt{1 - \nu_A} \right) \check{c} \\ P_c &= 1 - P_d \\ P_e &= \sqrt{2\alpha(1 - \nu_A)} + \left(\sqrt{2\alpha\nu_A} - \sqrt{2\alpha(1 - \nu_A)} \right) \check{c} = \sqrt{2\alpha} \left(\sqrt{1 - \nu_A} + \left(\sqrt{\nu_A} - \sqrt{1 - \nu_A} \right) \check{c} \right) \end{aligned}$$

For the first 3 parts of the proposition, it thus suffices to show that α and \check{c} both increase in β_e and decrease in β_c . For \check{c} , this is trivial. For α , define

$$Y = \int_0^{\check{c}} \left(\nu_P + \frac{1}{2} - \frac{\beta_c v}{2} \right) dv + \int_{\check{c}}^1 \left(2 - \frac{\beta_e}{2} \right) \nu_P dv$$

so that

$$\begin{aligned} U_P &= (1 - \alpha) \left\{ \sqrt{2\alpha(1 - \nu_A)} 2\nu_P + (1 - \sqrt{2\alpha\nu_A}) (2 - \beta_e) \nu_P + \left(\sqrt{2\alpha\nu_A} - \sqrt{2\alpha(1 - \nu_A)} \right) Y \right\} \\ &= (1 - \alpha) (2 - \beta_e) \nu_P + (1 - \alpha) \sqrt{2\alpha} \left(\sqrt{1 - \nu_A} 2\nu_P - \sqrt{\nu_A} (2 - \beta_e) \nu_P + \left(\sqrt{\nu_A} - \sqrt{1 - \nu_A} \right) Y \right) \end{aligned}$$

Note that $\frac{dY}{d\beta_e} = -\frac{\nu_P}{2} (1 - \check{c})$ and $\frac{dY}{d\beta_c} = -\frac{\check{c}^2}{4}$. Note further that

$$\frac{dU_P}{d\alpha} = -(2 - \beta_e) \nu_P + \frac{1 - 3\alpha}{\sqrt{2\alpha}} \left(\sqrt{1 - \nu_A} 2\nu_P - \sqrt{\nu_A} (2 - \beta_e) \nu_P + \left(\sqrt{\nu_A} - \sqrt{1 - \nu_A} \right) Y \right)$$

so that at the optimum $\alpha < \frac{1}{3}$ (where I use the fact that $2\nu_P \geq Y \geq (2 - \beta_e) \nu_P$ to sign the last factor of the derivative above). It also follows that

$$\begin{aligned} \frac{\partial^2 U_P}{\partial \alpha \partial \beta_e} &= \nu_P + \frac{1 - 3\alpha}{\sqrt{2\alpha}} \left(\sqrt{\nu_A} \nu_P + \left(\sqrt{\nu_A} - \sqrt{1 - \nu_A} \right) \left(-\frac{\nu_P}{2} (1 - \check{c}) \right) \right) \\ &= \nu_P + \frac{1 - 3\alpha}{\sqrt{2\alpha}} \left(\sqrt{\nu_A} \left(\nu_P - \frac{\nu_P}{2} (1 - \check{c}) \right) + \sqrt{1 - \nu_A} \frac{\nu_P}{2} (1 - \check{c}) \right) > 0 \end{aligned}$$

and further

$$\frac{\partial^2 U_P}{\partial \alpha \partial \beta_c} = \frac{1 - 3\alpha}{\sqrt{2\alpha}} \left(\sqrt{\nu_A} - \sqrt{1 - \nu_A} \right) \left(-\frac{\check{c}^2}{4} \right) < 0$$

The last part of the proof follows directly. ■

B The Effect of Complements versus Substitutes

This appendix considers the effect of complements versus substitutes on the delegation mechanism. As I mentioned before, delegation will increase the agent's effort if and only if effort is a complement to the decision.

To obtain this results formally, I start from the model of section 2, but consider the subgame starting in period 1d. In other words, I take α , w , c_e , and c_c as exogenously given. Also, in order to capture both substitutes and complements and to keep the analysis maximally transparent, I will consider variations on the specification of section 2 for the probability of success (and project return) Π .

Let me first formally show the intuition that effort will be higher under delegation if and only if effort and decisions are complements. This result is actually demonstrated most transparently by simplifying the specification to a probability of success Π that is increasing in e and d_A , which includes the specification of section 2. Let $J_A \in \{A, P\}$ denote the identity of the player who decides on decision D_A , and let \hat{e} denote the agent's choice of effort. The following proposition then captures formally the result that effort will be higher under delegation if effort and decisions are complements, and lower if they are substitutes.

Proposition 1 *If $\frac{\partial \Pi(e, d_A=1)}{\partial e} \geq \frac{\partial \Pi(e, d_A=0)}{\partial e} \forall e$, then $\hat{e}(J_A = A) \geq \hat{e}(J_A = P)$. If, on the contrary, $\frac{\partial \Pi(e, d_A=1)}{\partial e} \leq \frac{\partial \Pi(e, d_A=0)}{\partial e} \forall e$, then $\hat{e}(J_A = A) \leq \hat{e}(J_A = P)$.*

Proof: Let α_i denote the share of project revenue that goes to player i , let $Z_i = \operatorname{argmax}_{D_A \in \{X, Y\}} E_i[\alpha_i \Pi(e, d_A)]$ denote the best action according to player i , and let $Q_{i,j} = E_i[d_A \mid D_A = Z_j]$ denote i 's estimate of the probability that j is right. By revealed preference $Q_{A,A} \geq Q_{A,P}$, or $Q_{A,A} - Q_{A,P} \geq 0$. If now $\frac{\partial \Pi(e, d_A=1)}{\partial e} \geq \frac{\partial \Pi(e, d_A=0)}{\partial e} \forall e$, then

$$(Q_{A,A} - Q_{A,P}) \frac{\partial \Pi(e, 1)}{\partial e} \geq (Q_{A,A} - Q_{A,P}) \frac{\partial \Pi(e, 0)}{\partial e}$$

or

$$Q_{A,A} \frac{\partial \Pi(e, 1)}{\partial e} + (1 - Q_{A,A}) \frac{\partial \Pi(e, 0)}{\partial e} \geq Q_{A,P} \frac{\partial \Pi(e, 1)}{\partial e} + (1 - Q_{A,P}) \frac{\partial \Pi(e, 0)}{\partial e}$$

or

$$\frac{\partial}{\partial e} E_A[\Pi(e, d_A) \mid D_A = Z_A] \geq \frac{\partial}{\partial e} E_A[\Pi(e, d_A) \mid D_A = Z_P]$$

or, with $G(e, j) = j E_A[\alpha \Pi(e, d_A) \mid D_A = Z_A] + (1 - j) E_A[\alpha \Pi(e, d_A) \mid D_A = Z_P]$,

$$\frac{\partial^2 G(e, j)}{\partial e \partial j} \geq 0$$

At the same time, using notation $c(e) = \beta_e c_e e$,

$$\hat{e}(J_A = A) = \operatorname{argmax}_{e \in \{0,1\}} E_A[\alpha \Pi(e, d_A) - c(e) \mid D_A = Z_A] = \operatorname{argmax}_{e \in \{0,1\}} G(e, 1) - c(e)$$

while

$$\hat{e}(J_A = P) = \operatorname{argmax}_{e \in \{0,1\}} E_A[\alpha \Pi(e, d_A) - c(e) \mid D_A = Z_P] = \operatorname{argmax}_{e \in \{0,1\}} G(e, 0) - c(e)$$

The proof of the first part then follows by monotone comparative statics. The second part is analogous. ■

This result suggests straightforward implications for delegation and centralization: when effort and decisions are complements, delegation should increase in the importance of effort, while the opposite is true when effort and decisions are substitutes. To study that issue, consider the following slight elaboration of the specification in section 2:

$$\Pi(\gamma) = d_A + d_P - \beta_c c_c (1 - C) - \beta_e [\gamma(1 - e)d_A + (1 - \gamma)e(d_A - 1)]$$

for $\gamma \in [0, 1]$, which equals the original specification when $\gamma = 1$. Note that effort and the decision are complements if and only if $\gamma \geq 1/2$ and they are substitutes if and only if $\gamma \leq 1/2$. The following proposition then confirms the result that an increase in the importance of effort leads to more delegation if effort and decisions are complements but not so if they are substitutes. Let \hat{J}_A denote the person who optimally decides on D_A from the perspective of the principal.

Proposition 2 *When $\gamma > 1/2$, then there exists (for any $(\nu_A, \nu_P, \beta_c, c_c, c_e)$ and (α, w)) a $\hat{\beta}$ such that $\hat{J}_A = A$ if $\beta_e \geq \hat{\beta}$, and $\hat{J}_A = P$ otherwise. If $\gamma < 1/2$, $\hat{J}_A = P$ for any set of parameters.*

Proof: Let Z_i denote the action that player i considers best. Note that A exerts effort iff $\alpha\beta_e[\gamma E_A[d_A] + (1 - \gamma)(1 - E_A[d_A])] \geq \beta_e c_e^2/2$ or $\sqrt{2\alpha[(1 - \gamma) + (2\gamma - 1)E_A[d_A]]} \geq c_e$. Let $\underline{c} = \sqrt{2\alpha[(1 - \gamma) + (2\gamma - 1)(1 - \nu_A)]}$ and $\bar{c} = \sqrt{2\alpha[(1 - \gamma) + (2\gamma - 1)\nu_A]}$.

Consider first the case that $\gamma > 1/2$. If $\underline{c} \geq c_e$ then A will always exert effort, if $\bar{c} \geq c_e \geq \underline{c}$ then A will exert effort iff $D_A = Z_A$, and if $c_e \geq \bar{c}$ then A will never exert effort. Since these 3 cases do not depend on β_e , I can show the result case by case.

If $\underline{c} \geq c_e$, so that A always exerts effort, then P doesn't gain from allowing $D_A = Z_A$ and will therefore make sure that $D_A = D_P = Z_P$, so that $\hat{J}_A = P$ for any set of parameters such that $\underline{c} \geq c_e$.

If $\bar{c} \leq c_e$, so that A never exerts effort, P again doesn't gain from allowing $D_A = Z_A$, so that she will make sure that $D_A = D_P = Z_P$, so that $\hat{J}_A = P$ for any set of parameters such that $\bar{c} \leq c_e$.

If, finally, $\bar{c} \geq c_e \geq \underline{c}$, so that A exerts effort iff $D_A = Z_A$, then P has the following choices:

1. $D_A = D_P = Z_P$, but $e = 0$ when $Z_A \neq Z_P$, so that $U_P = (1 - \alpha) \left(2\nu_P - \frac{\beta_e}{2} (\gamma\nu_P + (1 - \gamma)(\nu_P - 1)) \right)$.
2. $D_P = Z_P$, $D_A = Z_A$, and $e = 1$, so $U_P = (1 - \alpha) \left(\nu_P + \frac{\nu_P + (1 - \nu_P)}{2} - \frac{\beta_c c_c}{2} - \beta_e (1 - \gamma) \left(\frac{\nu_P + (1 - \nu_P)}{2} - 1 \right) \right)$.

Note that in this case $\hat{J}_A = A$ if and only if case 2 is optimal. So I need to show that there exists a $\hat{\beta}$ such that case 2 is optimal iff $\beta_e \geq \hat{\beta}$. Some algebra shows that this is indeed true with $\hat{\beta} = \frac{\beta_c c_c + 2\nu_P - 1}{\nu_P}$.

Consider now the case that $\gamma < 1/2$. A will exert effort iff $\sqrt{2\alpha[(1 - \gamma) - (1 - 2\gamma)E_A[d_A]]} \geq c_e$. It follows that if $\sqrt{2\alpha[(1 - \gamma) - (1 - 2\gamma)\nu_A]} \geq c_e$ then A will always exert effort, if $\sqrt{2\alpha[(1 - \gamma) - (1 - 2\gamma)(1 - \nu_A)]} \geq c_e \geq \sqrt{2\alpha[(1 - \gamma) - (1 - 2\gamma)\nu_A]}$ then A will exert effort iff $D_A = Z_P$, and if $c_e \geq \sqrt{2\alpha[(1 - \gamma) - (1 - 2\gamma)(1 - \nu_A)]}$ then A will never exert effort. It follows further that P will always make sure that $D_A = Z_P$ so that $\hat{J}_A = P$ for all parameters. ■

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